CHEM 3523 001 Spring 2023

Name: KEY
ID:

Midterm Exam #2

Answer Sheet: (The conceptual questions are multiple choice. List the letter that corresponds to the correct answer. For the calculation problems list under ***a) the final equation*** that gives the solution. Use only symbols, not intermediate numerical results. List under ***b) the final numerical result***. Make no mistakes when transferring the answers! Put your names on **both** answer sheets **and** the work pages, and **return all pages**! Conceptual questions are **0.5 pts** each, calculation problems **3+1 pts**. Maximum number of points you can get is **25 pts**!

General Infos:

- No programable calculators, smartphones, smartwatches, tablets, headphones, ... are allowed. Neither any notes or books.
- Any attempt of cheating or other forms of academic dishonesty will result in an automatic "F" for the course.
- **Show a picture ID** when leaving
- **Be considerate if you finish early**. Consider to stay till end, or at least be quite when leaving earlier to avoid distracting your fellow students!

Conceptual questions:

1) B
2) C
3) B
4) A
5) C
6) A
7) B
8) B
9) D
10) C

Problems & Calculations:

1a) $1/\lambda = R_H\left(\frac{1}{1^2} - \frac{1}{4^2}\right)$
1b) 97.75 nm

2a) $E_{photon} = h\nu = h\frac{c}{\lambda}$
2b) 1.69×10^{20}

3a) $I = h/8\pi^2 B \Rightarrow I = \mu d^2 \Rightarrow d\sqrt{I/\mu}$
3b) .11 nm

4a) $\lambda = h/p_E$
4b) .58 nm

5a) $A = \varepsilon c l$
5b) 1.713×10^3 $dm^3/mol \cdot cm$

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Conceptual Questions:

1. The mechanics of a given one-dimensional system is described by a time-independent Schrödinger equation. The probability density of finding a particle at a certain location is then proportional to
   a. The wave function $\Psi(x)$
   b. $|\Psi(x)|^2$
   c. Cannot be determined

2. Which of the following pairs of quantities can be measured together with arbitrary precision?
   a. x and p_x
   b. z and p_z
   c. x and p_z
   d. none of a) – c)

3. In quantum mechanics, measurable quantities are described by linear Hermitian operators. Is it true that the spectrum of eigenvalues of such an operator corresponds to the set of all possible measurements?
   a. False
   b. True

4. For a particle in a one-dimensional box, the probability to find the particle is always larger than zero at any place within the box.
   a. False
   b. True

5. The De Broglie wavelength of particles traveling with a certain velocity
   a. Is independent from its mass
   b. Increases with increasing mass
   c. Decreases with increasing mass

6. Compared to that of infrared light is the momentum of photons of ultraviolet light
   a. Higher
   b. Lower
   c. Is the same.

7. Fermions are particles with
    a. Integer spin
    b. Half-integer spin
    c. Do not have a spin

8. For a Helium atom in the ground state, the two electrons
    a. do not have a spin
    b. have opposite spins
    c. have the same spin

9. Diatomic molecules can be described as linear rotors. In this model, the difference between two energy levels is proportional to
    a. The distance between the two atoms
    b. The square of the distance between the two atoms
    c. The inverse distance between the two atoms
    d. The square of the inverse distance between the two atoms.

10. A molecule in an excited state can decay to the ground state either by stimulated emission or spontaneous emission. When the frequency of the transition doubles, the probability of spontaneous emission increases relative to that of stimulated emission by a factor
    a. 2
    b. 4
    c. 8
    d. does not change
    e. none of a)-d)

2. **A 60 W lamp emits light at a wavelength of 560 nm. How many photons does the lamp emit per second?**

$$\gamma = \frac{c}{\lambda}$$

$$E_{photon} = h\gamma = h\frac{c}{\lambda} = \frac{6.626 \times 2.9979 \times 10^{-26}}{560 \times 10^{-9}} J$$

$$= 3.5477 \times 10^{-19} J$$

$$n_{photon} = \frac{Watt \cdot t}{E_{photon}} = \frac{60 J/s \cdot 1s}{3.5477 \times 10^{-19} J}$$

$$= 1.69 \times 10^{20}$$

Problems and Calculations:

1. Calculate the wavelength (in nm) corresponding to the n=1 to n=4 transition in the hydrogen atom.

$$\frac{1}{\lambda} = R_H\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = R_H\,\frac{15}{16}$$

$$\Rightarrow \lambda = \frac{16}{15 \cdot R_H} = \frac{16}{15 \cdot 1.0968 \times 10^{7}\ 1/m}$$

$$= 0.9725 \times 10^{-7}\ m$$

$$= 97.25 \times 10^{-9}\ m$$

$$= 97.25\ nm$$

3. In the microwave spectrum of the diatomic molecule $^{12}C^{16}O$ the separation between lines ($\Delta\nu$) has been measured to be 120000 MHz. Calculate the interatomic distance (in nm).

$$\nu = 2(J+1)B \Rightarrow \Delta\nu = 2B \Rightarrow B = \frac{\Delta\nu}{2} = 6\times10^{10} Hz$$

$$B = \frac{h}{8\pi^2 I} \Rightarrow I = \frac{h}{8\pi^2 B} = \frac{6.626\times10^{-34}}{8\cdot\pi^2\cdot 6\cdot10^{10}}$$

$$= 1.399\times10^{-46}\ kg\,m^2$$

$$I = \mu d^2 \Rightarrow d = \sqrt{I/\mu}$$

$$\mu = \frac{12\cdot16}{12+16}\cdot 1.661\times10^{-27}\ kg$$

$$= 1.139\times10^{-26}\ kg$$

$$= \sqrt{\frac{1.399}{1.139}10^{-20}}\ m$$

$$= \sqrt{1.228}\times10^{-10}\ m$$

$$= 1.11\times10^{-10}\ m$$

$$= 0.11\ nm$$

4. A photoelectric experiment shows that UV light with λ=248 nm is required to remove an electron from a metal plate. What is the de Broglie wavelength (in nm) of electrons if UV light of 130 nm is used?

$E_{photon} = h\nu$, $E_{photon} = E_{Km}^{electron} + V^{metal}$

$= \frac{hc}{\lambda}$

$\Rightarrow V^{metal} = \frac{hc}{248 \times 10^{-9} m}$

$\Rightarrow E_{Km}^{electron} = \frac{p_e^2}{2m_e} = \frac{hc}{130 \times 10^{-9} m} - \frac{hc}{248 \times 10^{-9} m}$

$\Rightarrow p_e = \sqrt{2 m_e hc \frac{248 - 130}{130 \cdot 248} \frac{10^{-9}}{10^{-18}}}$

$= \sqrt{2 \cdot 9.109 \cdot 29979 \cdot 6.626 \cdot 0.00366 \cdot 10^{-48} \, Kg \frac{m}{s}}$

$= \sqrt{1.3245 \times 10^{-48}} \, Kg \frac{m}{s}$

$= 1.151 \times 10^{-24} \, Kg \frac{m}{s}$

$\lambda_E = \frac{h}{p_e} = \frac{6.626 \times 10^{-34}}{1.151 \times 10^{-24}} \, m$

$= 5.757 \times 10^{-10} \, m$

$= 0.58 \times 10^{-9} \, m$

$= 0.58 \, nm$

5. A 20 μM solution of a substance gave an absorbance of 0.1028 with a light path of 3 cm. Calculate the molar absorption coefficient.

$A = \varepsilon \cdot c \cdot l$

$\Rightarrow \varepsilon = \frac{A}{c \cdot l}$

$c = 20 \times 10^{-6}$ M

$l = 3$ cm

$= \frac{0.1028}{6 \times 10^{-5}} = 6.01713 \times 10^{5} = 1.713 \times 10^{3} \frac{dm^3}{mol \cdot cm}$